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PATENT

LINEAR BRUSHLESS DC MOTOR WITH IRONLESS ARMATURE ASSEMBLY

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Related Applications

The present application claims priority under 35 U.S.C. §119(e) from provisional application number 60/258,205, filed December 26, 2000.

Technical Field

The present invention relates generally to linear motion devices, and in particular to a linear brushless DC motor with an ironless armature assembly and substantially constant force throughout its stroke.

Background Art

One of the simplest possible linear motion devices is a cylindrical linear voice coil actuator. However, these are limited stroke devices. If long strokes are required, a commutated linear voice coil actuator also known as a linear brushless DC motor can be used (Fig. 1A). An example of a linear brushless non-commutated device with flux-focused magnetic circuits can be found in the moving coil actuator disclosed in U.S. Pat. No. 5,345,206, assigned to BEI Electronics, Inc., the assignee of the subject application. U.S. Pat. No. 5,345,206 is hereby incorporated by reference into the subject application.

When linear motion devices are used in a servo system, the mass of a moving part (armature assembly) should be minimized. In addition, all the forces created by a motor, except for the force in the direction of motion, should be eliminated or minimized. And finally, to achieve a smooth operation, the force developed by a servomotor should remain constant throughout the stroke.

Summary Of The Invention

It is therefore an object of the present invention to provide a linear motion device that has a long stroke and moving parts of low mass.

It is another object of the present invention to provide a linear motion device in the form of a linear brushless DC motor in which the forces created by the motor, other than in the direction of motion, are minimized.

It is a further object of the present invention to provide a linear brushless DC motor having a smooth operation in which the force developed remains constant throughout the stroke.

It is a still further object of the present invention to provide a linear brushless DC motor having a smooth operation in which the force developed remains constant throughout the stroke by using a sinusoidal commutation of a three phase motor.

In accordance with the present invention there is provided a linear brushless DC motor with ironless armature assembly and a field assembly tailored to achieve a desired constant force versus stroke characteristic, for example, as set forth in Fig. 2.

The present invention comprises an armature assembly, and a field assembly that includes a plurality of permanent magnets each having a length, and a plurality of pole pieces each having a length. The ratio between the length of the plurality of permanent magnets and the length of the plurality of pole pieces is tailored to achieve a constant force versus stroke characteristic.

In accordance with the present invention, a brushless DC motor is provided comprising an armature assembly; and a field assembly positioned with respect to the armature assembly so that an air gap is formed between them. The field assembly includes a plurality of permanent magnets each having a length, and a plurality of pole pieces each having a length. The ratio between the length of the plurality of permanent magnets and the length of the plurality of pole pieces is selected to provide a sinusoidal distribution of a normal component of flux density in the air gap.

These and other objectives, features and advantages of the present invention will be more readily understood upon consideration of the following detailed description of the invention and the accompanying drawings.

Brief Description of the Drawings

Fig. 1A is an illustration of a linear brushless DC motor.

Fig. 1B is a cross section of the linear voice coil actuator disclosed in prior US Patent 5,345,206.

Fig. 2 is simplified cross section showing the housing, field assembly and armature assembly of an embodiment of the linear brushless DC motor of the present invention.

Fig. 3 is a simplified cross section of the field assembly of an embodiment of the linear brushless DC motor of the present invention.

Fig. 4 is a simplified cross section showing details of an end cap of an embodiment of the linear brushless DC motor of the present invention.

Fig. 5 illustrates a sinusoidal distribution of the normal component of the flux density in the air gap in accordance with one embodiment of the present invention.

Fig. 6 illustrates a sinusoidal force versus entire stroke curve obtained for a one phase or combination of two phases of a three-phase motor in accordance with one embodiment of the present invention.

Figs. 7A and 7B are a perspective view and a cross section, respectively, of the armature assembly of one embodiment of the present invention.

Detailed Description Of The Invention

According to the present invention, the linear brushless DC motor 10 includes an armature assembly 13, a field assembly 12 "sandwiched" between two end caps 14, 16 made from soft magnetic material, and two halves 18, 20 of a housing also made from the soft magnetic material. The field assembly 12, as well as the end caps 14, 16 and the housing 18, 20 constitute a common magnetic circuit.

The field assembly 12 comprises of a non-magnetic rod 22, which defines a common field assembly axis, and onto which axially magnetized cylindrical permanent magnets 24, soft magnetic pole pieces 26 and two axially magnetized end permanent magnets 28, 30 are installed, for example as set forth in Fig. 3.

The pole pieces 26 are located between the permanent magnets 24 that are magnetized in opposite directions. All the magnets 24 and pole pieces 26 are bonded together. For centering purposes, both ends of the field assembly rod 22 fit into the cylindrical bores 32 provided in the end caps 14, 16. The two halves 18, 20 of the housing fit into the circular cavities 34 also machined in the end caps 14, 16. To prevent the angular misalignment of the housing halves 18, 20, they are secured in place at both ends with the locking pins 36. See, Fig. 4.

Although the configuration of the magnetic components of the linear motor of the present invention is similar to that of a moving coil actuator disclosed in U.S. Pat. No. 5,345,206 to Morcos, which is assigned to BEI Electronics, Inc., assignee of the subject application, there are two substantial differences:

1) The design of U.S. Pat. No. 5,345,206 was aimed to create flux-focused magnetic circuits whereas the present invention allows one to achieve a sinusoidal distribution of the normal component of the flux density in the air gap, as illustrated in Fig. 5. The sinusoidal distribution is obtained by selecting the appropriate ratio between the length of the permanent magnets and the length of the pole pieces. For example, referring to the pole pieces and the permanent magnets (other than the end permanent magnets) in Fig. 3, one such suitable ratio can be a pole piece length which is two-thirds (2/3) the length of the permanent magnet. The end magnet length was also selected accordingly.

2) In order to get a sinusoidal force vs. entire stroke curve for one phase or a combination of the two phases of a three-phase motor, such as shown in Fig. 6, special attention was paid to selection of the proper ratio between the pole piece length ($l_{P.P.}$) and the length of the end pole piece ($l_{E.P.P}$) which is an integral part of the end cap. Referring to Fig. 2, an example is shown of one such suitable ratio which is an end pole piece length ($l_{E.P.P}$) which is one-half (1/2) the pole piece length ($l_{P.P}$).

The armature assembly 13 includes a non-magnetic cylindrical coil base 38 with the cavities for the coils 40, the three-phase winding and the two mounting brackets 42, 44 to be connected to the load, as illustrated in Fig. 7.

The armature assembly 13 may slide on motor's own linear bearings (not shown) or may be supported by the linear bearings of the load.

The terms and expressions which have been employed herein are intended as terms of description and not of limitation, and there is no intent in the use of such terms and expressions of excluding equivalents of the features shown and described, or portions thereof, it being recognized that various modifications are possible within the scope of the invention claimed.